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Parveen Khurana

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Say Hi to Machine Learning



Parveen Khurana Nov 27, 2019 · 23 min read

We have seen that there are **four challenges** that typically any **large scale rule-based system** actually faces:

- i.) Lots of data
- ii.) A lot of rules which are hard to write down
- iii.) And sometimes the rules themselves are inexpressible we can't even write them as a Boolean condition.
- iv.) Rules being unknown.

To overcome these limitations, we look at **Machine Learning**.

The idea here is that instead of having a human who comes with the rules(of expert-based systems) in their head and then tries to express these rules as programs, can we remove the human of the loop and introduce a machine that directly accesses this data and learns the program(function) on its own.


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92	82	yes	9.2	3	2
83	75.2	yes	7.2	1	0
75	70	no	6.4	0	1
96	95	yes	9.5	5	4
90	89	yes	8.8	2	1
78	82	yes	7.6	0	0
86	88	yes	8.4	1	1

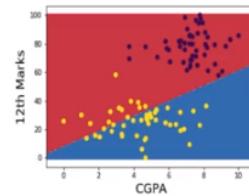
```
def f(x):
    i=0
    max_epochs=100
    w = rand()
    while(i<max_epochs):
        dw = grad(w,w*x)
        w = w - lr*dx
        i += 1
    return w*x
```

YES / NO

Output

So, instead of a human coding out the function/program, the machine has to somehow figure out this function, and not only that, it has to figure out some parameters as well.

$$\hat{y} = f(x_1, x_2)$$



blue	hire
red	don't hire

10th marks	12th marks	graduate	CGPA	projects	awards
92	82	yes	9.2	3	2
83	75.2	yes	7.2	1	0
75	70	no	6.4	0	1
96	95	yes	9.5	5	4
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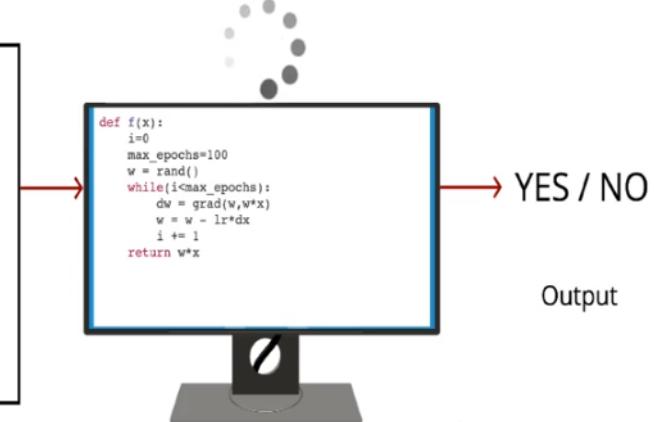
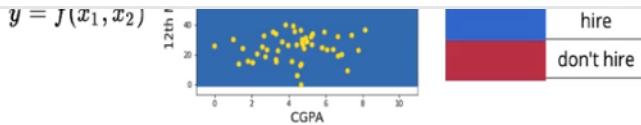
YES / NO

Output

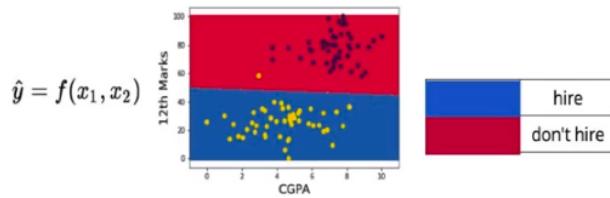
Parameter set 1


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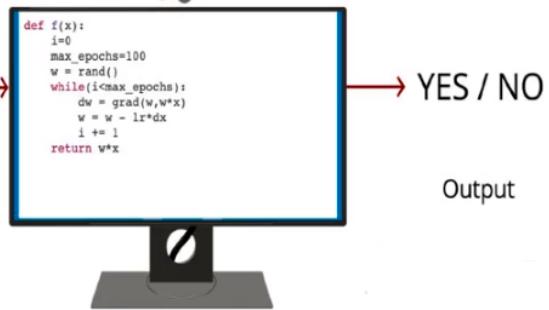
10th marks	12th marks	graduate	CGPA	projects	awards
92	82	yes	9.2	3	2
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96	95	yes	9.5	5	4
90	89	yes	8.8	2	1
78	82	yes	7.6	0	0
86	88	yes	8.4	1	1



Parameter set 2



10th marks	12th marks	graduate	CGPA	projects	awards
92	82	yes	9.2	3	2
83	75.2	yes	7.2	1	0
75	70	no	6.4	0	1
96	95	yes	9.5	5	4
90	89	yes	8.8	2	1
78	82	yes	7.6	0	0
86	88	yes	8.4	1	1



Parameter set 3

So, this is what a typical machine learning set up looks like. We are given a lot of data. And now we have this function which depends on all of this data(all the rows all the features), and now our decision relies on this function, we just don't know what this function is, so unlike the other case where we were able to write this function as series of if-else conditions, here we don't even know what the function is. And unlike the other case where we were able to give certain weights to certain inputs(whether Java is

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Now we can tell a machine that we think there is some relation between the input and the output, we think the relation comes from this family of functions(either the Linear family or polynomial family or from Non-Linear family, etc.) and we could just tell the machine, look at this data look at the inputs, look at the outputs, try out all these functions with different parameters and figure out which functions and with what parameters best explains the relationship between the input and the output.

So, this task is what we are outsourcing to the machine. And once the machine gives us that function, we just need to code up that function and for any new input, we could derive the output just by plugging in the input to that function. So, that's what Machine Learning enables us to do.

So, now the crux is how do you define these functions? We can't just try arbitrary functions, so what are the good set of functions to try and once the function is available, how do we estimate the values of these parameters.

Six Elements of Machine Learning:

- i.) Data
- ii.) Task
- iii.) Model
- iv.) Loss
- v.) Learning Algorithm
- vi.) Evaluation

Data:

Data is the fuel of Machine Learning. Today we have data everywhere whether be it on social media platforms like Facebook where we have text data, video data, audio data or be it on product websites like Amazon where we have something known as structured data which is in form of a table or we have reviews or product picture or some videos to describe how to use the product and so on, or you could have something like gaana.com where we have a lot of audio or speech data. So, all forms of data are available on the internet. Just because so much data is available does not

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application:

So, the application is here that we are given a medical image and based on that input we want to be able to train a machine to find out whether there is an anomaly or not in that image.

scans	x						y
	2.3	5.9	...	11.0	-0.3	8.9	0
	-8.5	-1.7	...	-1.3	9.0	7.2	1
	-0.4	6.7	...	-2.4	4.7	-7.3	0
	1.6	-0.4	...	-4.6	6.4	1.9	1
	3.9	-4.1	...	6.7	-3.1	2.1	1
	5.1	3.7	...	1.8	-4.2	9.3	1

scans	x						y
	2.3	5.9	...	11.0	-0.3	8.9	0
	-8.5	-1.7	...	-1.3	9.0	7.2	1
	-0.4	6.7	...	-2.4	4.7	-7.3	0
	1.6	-0.4	...	-4.6	6.4	1.9	1
	3.9	-4.1	...	6.7	-3.1	2.1	1
	5.1	3.7	...	1.8	-4.2	9.3	1

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characteristic, in this case, it tells whether the input has an anomaly or not(maybe like brain tumor or any other sort of medical anomaly). So, for this, **we need data of the type (x, y) where x is the input and y is the output.** Only if we have abundant data of form (x, y) then only we can train a machine to learn a mapping between x and y. And then if we are given a new image, we should be able to predict the outcome for this. But if the only x is being provided, then there is not much that we can do.

And if the input contains an anomaly, then we would also like to locate the exact position of the anomaly example:

	-8.5	-1.7	...	-1.3	9.0	7.2	1
	-0.4	6.7	...	-2.4	4.7	-7.3	0
	1.6	-0.4	...	-4.6	6.4	1.9	1
	3.9	-4.1	...	6.7	-3.1	2.1	1
	5.1	3.7	...	1.8	-4.2	9.3	1

And y, in this case, output would not be just 0 or 1, it would be the co-ordinates of the bottom left corner and top right corner. And for this particular case, we would require the data in this form where we are provided with samples(image as the input) for which we have the coordinates of the bounding box(bottom left corner and top right corner) where the anomaly lies so that we can train the machine accordingly and the machine's job is to find the relationship between the input and the coordinates of the bounding box which would be the output in this case.

The second thing that we need to understand is that the data should be in a machine-readable format. So, in the case of an image, it's not very difficult, the image(medical scan) could be in the form of a 30X30 image which means it has 900 pixels, each of the pixels tells the RGB value of that particular cell, so we have 900 values which we enumerate as a single array, so that's what our input is and what we are trying to learn is a relationship which takes you from this input of 900 numbers to the output number.

[Open in app](#)**i.) Data should be in the form of (x, y).**

ii.) It should be in a machine-readable format(All the data is encoded as numbers).

And usually, the data is high dimensional, in this case, we have 30X30 image or 900 pixels, that means we have 900 numbers describing each data point/sample.

Let's take another example where we have a document and we would like to do sentiment analysis on that document to know whether the reviewer is talking something positive about the product or something negative about the product:

Document	x						y
Don't buy this MI 6 Pro, Speaker volume is very bad	1.9	3.2	...	-9.8	-6.7	1.2	negative
Delivered as shown. Good price and fits perfect	1.3	3.6	...	-5.4	9.1	2.3	positive
What a phone.. A handy epic phone. MI at its best ...	0.4	7.6	...	-0.1	-1.4	8.7	positive
Its look stunning in pictures , but not in real.	1.5	-0.8	...	7.8	8.4	0.3	negative
Amazing camera and battery. Good deal!	2.5	-5.7	...	0.9	5.3	-8.1	positive

So, here again, we need data in the form of (x, y) where x is the document and y is the label marked by a human. Now if have a lot of such data, we could build a machine learning agent to understand the relation between x and y such that if you give me a new document as the input at the test time, our agent would be able to output y using the function it has learned.

Secondly, in this case, as we have text data, we should have a way to represent this data in some form of numerical quantity because the function that we are going to learn is of the form

$$y = f(x)$$

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numbers.

And the data just need not be text or image, it could be a structured table, for example, it could be the past record of an employee like what was his appraisal ratings for years, how many teams did he work with, how many projects did we work on, what was his client satisfaction for every module he delivered, what was his salary at different levels, how many promotions he/she has got etc. So, all of these can be represented as structured data.

We could have text data, product reviews discussed above is an example.

Then we have the image data where we take the pixel values to represent it as numeric data. Even a video could be represented as numeric data as the video is just a collection of images/pictures.

And lastly, we have the speech data which we could represent as of different amplitudes, frequencies and so on.



1.3 -4.3 2.1 -6.7 ... 1.5 8.9 10.1 -4.5



2.6 7.9 -0.3 8.1 ... -4.2 0.3 1.2 9.4



-5.2 -3.2 4.2 0.3 ... 3.5 8.3 -1.4 -8.7



2.3 -5.6 -1.2 7.8 ... 9.9 10.1 -1.1 3.5



8.5 2.1 -6.3 5.3 ... 7.2 -1.3 -4.5 11.8

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Typically high dimensional \mathbb{R}^n

Now the question is **where do I get the data from?**

Data Curation: We have to curate this data.

There are lots of open data set repository available online:

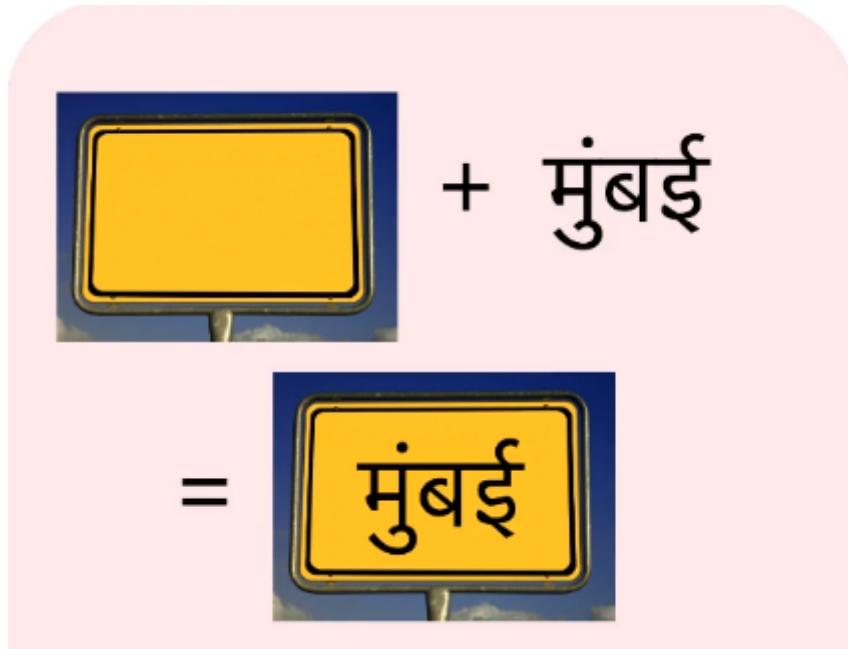


There are some online platforms where we curate the data where for example we could upload a piece of an image and we can ask workers all around the world and they label/draw out the bounding box where the word appears.




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create/get the empty signboard(using image editing tool we could create various templates of signboards), then we could take various names in Hindi, and then we use an image editing tool which takes these two things and pastes one on top of another. so, the net effect is that we get a lot of this signboard data.



We could also get a lot of data on Wikidata.

Task:

A task is nothing but a crisp definition of what your input is and what your output is.

Once we have the data, what do we do with the data?

Below is a typical example of the data. We have various things over here, it is a product page from Amazon. Let's look at all the data that we have here.

Hello John,

Redmi 6 Pro (Gold, 3GB RAM, 32GB Storage)

- 12MP + 5 MP AI dual camera;5MP front camera
- Display: 14.8 centimetres (5.84-inch) Full HD+ capacitive touchscreen with 2280x1080 pixels and 432 ppi pixel density .Height: 149.33mm,Width: 71.68mm,Thickness: 8.75mm,Weight: 178g.
- Memory, Storage & SIM: 3GB RAM | 32GB storage expandable up to 256GB | Dual SIM , 4G +4G, standby (one sim supports 4G at a time)
- Operating System and Processor: Android v8.1 Oreo operating system with 2.0GHz Qualcomm snapdragon 625 octa core processor
- Battery: 4000 mAH lithium Polymer battery
- Warranty: 1 year manufacturer warranty for device and 6 months manufacturer warranty for in-box accessories including batteries from the date of purchase
- Included in box: Adapter, USB Cable, Back Cover

Showing 1-8 of 14,506 reviews

Top Reviews

Niraj Rathor ★☆☆☆☆ DON'T Buy this Model MI 6 Pro

10 October 2018

Colour: Gold | Size: 32GB | Verified Purchase

Don't buy this MI 6 Pro .
Speaker volume is very bad & Low
Camera pics are not good at all special back cam having dual cam stabilization problem front cam like VGA pics
Heating issue
Battery drained very Fast

159 people found this helpful

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Technical Details

OS	Android
RAM	3GB
Screen Height	5.71
Product Dimensions	149.33x71.68x7.75mm
Weight	178g or 180g (with expandable memory)
Processor	Qualcomm Snapdragon 625 Octa-core (4x2.05GHz + 4x1.4GHz) Processor
Display technology	IPS LCD (TFT) 2.5D Gorilla Glass 3.0
Speaker features	Dual (L/R) Stereo Speaker (Dolby Atmos) with 3D sound
Other camera features	N/A
Front Camera	16MP Front Camera
Weight	177g
Color	Gold
Battery Power Rating	4080 mAh
Storage Options	Harder, Apple, 1000 Cable, Memory Card, User Guide, SIM Protection Tool and Back Cover

Display quality is top notch, overall the quality of the phone is very good. All metal body. Camera is good too. Touch smoothness is amazing. I will definitely recommend to buy this phone. The USB is not type C, it is the old one. This is the only con that I found till now. It has got 2 nano sim slots and a dedicated memory card slot (2+1). Other than the phone, amazon delivery service is a bit let down. It took 6 days to deliver the item from Calcutta to Assam. Whereas last year I bought 2 Redmi Note 4 (for me and my uncle) from flipkart and mi india website, if you recall, Mi had flash sale every Friday. Hence I bought both handset on different dates. To my surprise I placed the order on Friday and received the item on Sunday on one occasion and Monday on the other occasion, which the shipped through ekart and FedEx respectively. Merely in 2-3 I got my phone. But Amazon's courier service is a total letdown as compared ekart and FedEx.

72 people found this helpful

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FAQs

- Q Does it have a noise cancelling mic?
- Q Can I use two apps on the same screen?
- Q Can it run two WhatsApp accounts at the same time?
- Q Can I connect my pen drive to the phone?
- Q Can I shoot high quality videos?
- Q Can I use two apps on the same screen?
A Yes, using the split screen option, you can use two apps at once.
- Q Can I shoot high quality videos?
A Yes, you can shoot Full HD video on the device.

We have image data, we have data in the structured description of the product, then we also have unstructured data as the reviews about the product, then we have the product description given by the Vendor which is a bit unstructured but also may have structure. Then we have the information about the related products which are similar to this product. Then we FAQs and other questions asked by users and their answers.

Xiaomi Mi 6 Pro (3GB RAM, 32GB Storage)

Showing 1-8 of 14,500 reviews

Top Reviews

Don't Buy this Model: Mi 6 Pro

10 October 2018
Colour Gold - Size: 32GB | Verified Purchase
Don't buy this Mi 6 Pro .
Speaker volume is very bad & Low.
Camera pics are not good at all special back cam having dual cam stabilization problem front cam like VGA pic.
Heating issue
Battery drained very fast

Ultimate phone

16 October 2018
Colour Gold - Size: 32GB | Verified Purchase
Display quality is top notch, overall the quality of the phone is very good. All metal body. Camera is good too. Touch smoothness is amazing. I will definitely recommend to buy this phone. The USB is not type C, it is the old one. This is the only con that I found till now. It has got 2 nano sim slots and a dedicated memory card slot (2+1). Other than the phone, amazon delivery service is a bit let down. It took 6 days to deliver the item from Calcutta to Assam. Whereas last year I bought 2 Redmi Note 4 (for me and my uncle) from flipkart and mi india website, if you recall, Mi had flash sale every Friday. Hence I bought both handset on different dates. To my surprise I placed the order on Friday and received the item on Sunday on one occasion and Monday on the other occasion, which the shipped through ekart and FedEx respectively. Merely in 2-3 I got my phone. But Amazon's courier service is a total letdown as compared ekart and FedEx.

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FAQs

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data is thrown at you what are the different tasks that you can do with this data.

For the above case, we could have many different tasks. One task could be:

Product Details:

- 12MP + 5 MP AI dual camera/SMP front camera
- Display: 14.8 centimetres (5.84-inch) Full HD+ capacitive touchscreen with 2280x1080 pixels and 432 ppi pixel density
- Height: 149.33mm;Width: 71.68mm;Thickness: 8.75mm;Weight: 178g.
- Memory, Storage & SIM: 3GB RAM | 32GB storage expandable up to 256GB | Dual SIM, 4G +4G, standby (one sim supports 4G at a time)
- Operating System and Processor: Android v8.1 Oreo operating system with 2.0GHz Qualcomm snapdragon 625 octa core processor
- Battery: 4000 mAH lithium Polymer battery
- Warranty: 1 year manufacturer warranty for device and 6 months manufacturer warranty for in-box accessories including batteries from the date of purchase
- Included in box: Adapter, USB Cable, Back Cover

User Review:

5.0 ★★★★★ **New Father**
10 October 2018
Colour: Gold | Size: 32GB | Verified Purchase

DON'T Buy this Model MI 6 Pro
Don't buy it. It is very bad & Low speaker volume is very bad & Low Camera pics are not good at all. Special back cam having dual cam stabilization problem front cam like VGA pic. Battery drained very fast

159 people found this helpful

Helpful **Comment** **Report abuse**

Amazon Customer
16 October 2018
Colour: Gold | Size: 32GB | Verified Purchase

Display quality is top notch, overall the quality of the phone is very good. All metal body. Camera is good too. Touch smoothness is amazing. I will definitely recommend to buy this phone.

The USP is not clear. It is the old one. This is the only con that I found till now. It has got 2 nano sim slots and a dedicated memory card slot (SD).

Other than the phone, amazon delivery service is a bit slow. It took 6 days to deliver the item from Calcutta to Amazon. I am not sure if it is because of the Amazon 2 delivery slot or not.

I have had flash sale every Friday. Hence I bought both handset on different dates. To my surprise I placed the order on Friday and got the phone on Saturday on one occasion and Monday on the other occasion, while the shipped through ekart and FedEx respectively. Merely in 2-3 I got my phone. But Amazon's courier service is a total larkdom as compared ekart and FedEx.

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Helpful **Comment** **Report abuse**

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A Yes, you can shoot Full HD videos on the device.

Input

```
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```

Output

Technical Details

ID	Gold
Size	32GB
Net Weight	178g
Product Dimensions	149.33x71.68x8.75mm
Material	All-metal
Memory	3GB RAM 32GB
Storage	expandable up to 256GB
Processor	Qualcomm snapdragon 625 octa core
Operating System	Android v8.1 Oreo
Battery	4000 mAH lithium Polymer
Warranty	1 year manufacturer warranty for device and 6 months manufacturer warranty for in-box accessories including batteries from the date of purchase
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Given the data in the red box in the above image as the input which is some unstructured information about the product provided by the vendor, can we train a machine to fill in a table(green box in the above image) which would be a structured data? So, this is one of the tasks which could be accomplished using an abundant of the above data cases.

Another task could be:

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Output

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Product Dimensions	149.33x71.68x8.75mm
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combination of these two), and using this we also have information about the FAQs that are important for this product. So, now if we are provided with new product reviews and specifications, the task is to come up with FAQs of this product.

Yet another task we could have is:

The screenshot shows a product page for a smartphone. At the top, there's a summary of the phone's features: 12MP + 5 MP AI dual camera/SMP front camera, Display: 14.8 centimetres (5.84-inch) Full HD+ capacitive touchscreen with 2280x1080 pixels and 432 ppi pixel density, Height: 149.33mm, Width: 71.68mm, Thickness: 8.75mm, Weight: 178g, Memory, Storage & SIM: 3GB RAM | 32GB storage expandable up to 256GB | Dual SIM, 4G + 4G, standby (one sim supports 4G at a time), Processor: Octa-core 2.0GHz Qualcomm snapdragon 625 octa core processor, Battery: 4000 mAh lithium Polymer battery, Warranty: 1 year manufacturer warranty for device and 6 months manufacturer warranty for in-box accessories including batteries from the date of purchase, and Included in box: Adapter, USB Cable, Box Contents, and a quick start guide.

Reviews:

- Review 1:** 5 stars, "DON'T buy this Model Mi 6 Pro", posted on 10 October 2018, Cello Gold - Score 32GB - Verified Purchase. The review states: "Speaker volume is very bad & Low. Camera pics are not good at all special back cam having dual cam stabilization problem front cam like VGA pics. Battery drained very fast".
- Review 2:** 5 stars, "Ultimate phone", posted on 16 October 2018, Amazon Customer. The review states: "Display quality is top notch, overall the quality of the phone is very good. All metal body. Camera is good too. The screen is not type-C, it is Type-A. This is the only con I found with this phone. It has got 2 nano sim slots and a dedicated memory card slot (2+1). Delivery was very fast. Amazon's courier service is bit let down. It took 6 days to deliver the item from Calcutta to Amazon. Whereas last year I bought 2 Redmi Note 4 (1 for me and my uncle) from Flipkart and mi website, if you order on Friday and received the item on Sunday on one occasion and Monday on the other occasion, which the shipped through ekart and FedEx respectively. Merely in 2-3 i got my phone. But Amazon's courier service is a total red herring. I am not satisfied with their delivery".

FAQs:

- Q: Does it have a noise cancelling mic?
- Q: Can I use two apps on the same screen?
- Q: Can it run two WhatsApp accounts at the same time?
- Q: Can I connect my pen drive to the phone?
- Q: Can I shoot high quality videos?

Input

The input interface shows a review from Ning Kumar and a list of questions. The review is identical to the one in the product details section above. The list of questions includes:

- Q: Does it have a noise cancelling mic?
- Q: Can I use two apps on the same screen?
- Q: Can it run two WhatsApp accounts at the same time?
- Q: Can I connect my pen drive to the phone?
- Q: Can I shoot high quality videos?

Output

The output interface shows a single question and its answer:

Q: Can I shoot high quality videos?
A: Yes, you can shoot Full HD videos on the device.

Given the information about the reviews, product specification, and FAQs, can we answer any question that a random user is asking?

Another task that we could do here is that we have information about the user, we know what product page the user is looking at currently, what are the different attributes of that product and based on that we could recommend new products to this user based on his purchase history also.


[Open in app](#)

The screenshot shows a mobile application interface. At the top, there's a navigation bar with a back arrow and a search bar containing the text "Output". Below the search bar, there's a "Hello John," message. The main content area displays a product review for the "Redmi 6 Pro (Gold, 3GB RAM, 32GB Storage)". The review has a rating of 4.5 stars and 14,000 reviews. It includes a summary and several paragraphs of text. Below the review, there's a section titled "Related to Items you've viewed" with three product cards:

- Oppo F7 (Inferno Black, 6GB RAM, 128GB Storage) - 4.2 stars, ₹ 21,999.00 online
- Realme 2i (Oriental Blue, 3GB RAM, 32GB Storage) - 4.5 stars, ₹ 11,999.00 online
- Redmi 6 Pro (Black, 4GB RAM, 64GB Storage) - 4.5 stars, ₹ 12,999.00 online

Let's take another example:

The screenshot shows Aamir Khan's Facebook profile. He has 10.5M likes, 10.5K posts, and 10.5M followers. His bio includes his website www.aamirkhan.com. The timeline shows three posts:

- Post 1:** A photo of Aamir Khan and Shah Rukh Khan. This post has 14K likes, 178K comments, and 1,000 shares.
- Post 2:** A photo of Aamir Khan and his family at a meal. This post has 11K likes, 102K comments, and 79 shares.
- Post 3:** A photo of Aamir Khan working out with his son. This post has 12K likes, 202 comments, and 79 shares.

Here again, we have been provided with a lot of data. Several different tasks could be defined over here as well like:

[Open in app](#)

Input



Output

Shahrukh Khan



To identify activities from an image:

Input



[Open in app](#)

Output

Eating

To identify location/place from a given image:

Input



Output

Gym

Another task would be: based on a facebook post information, we could recommend similar posts or similar activities.

[Open in app](#)

Supervised

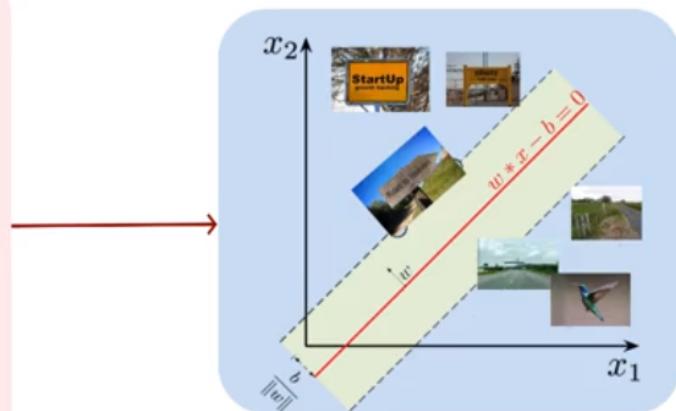


	$\rightarrow x$					y
	-8.5	-1.7	...	9.0	7.2	1
	-0.4	6.7	...	4.7	-7.2	0
	3.2	5.9	...	11.0	8.9	1
	2.7	3.1	...	-2.1	9.7	0
	3.9	7.8	...	-5.1	3.7	0
	7.1	0.9	...	1.5	-4.2	1

We can build a classifier that learns the relationship between x and y and the output of the classifier is 0 or 1 depending on whether the given input image contains text or it does not contain text.


[Open in app](#)

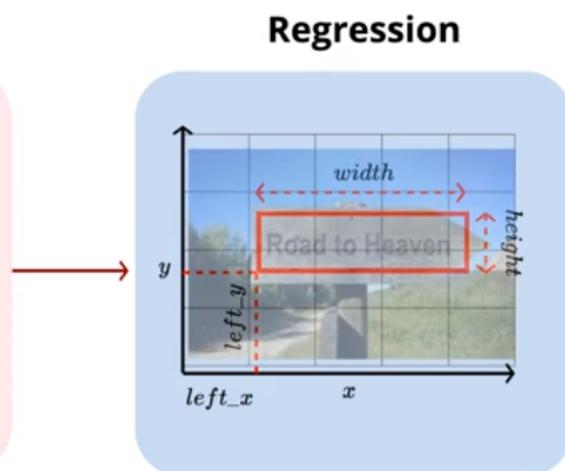
	\vec{x}					y
	-8.5	-1.7	...	9.0	7.2	1
	-0.4	6.7	...	4.7	-7.2	0
	3.2	5.9	...	11.0	8.9	1
	2.7	3.1	...	-2.1	9.7	0
	3.9	7.8	...	-5.1	3.7	0
	7.1	0.9	...	1.5	-4.2	1



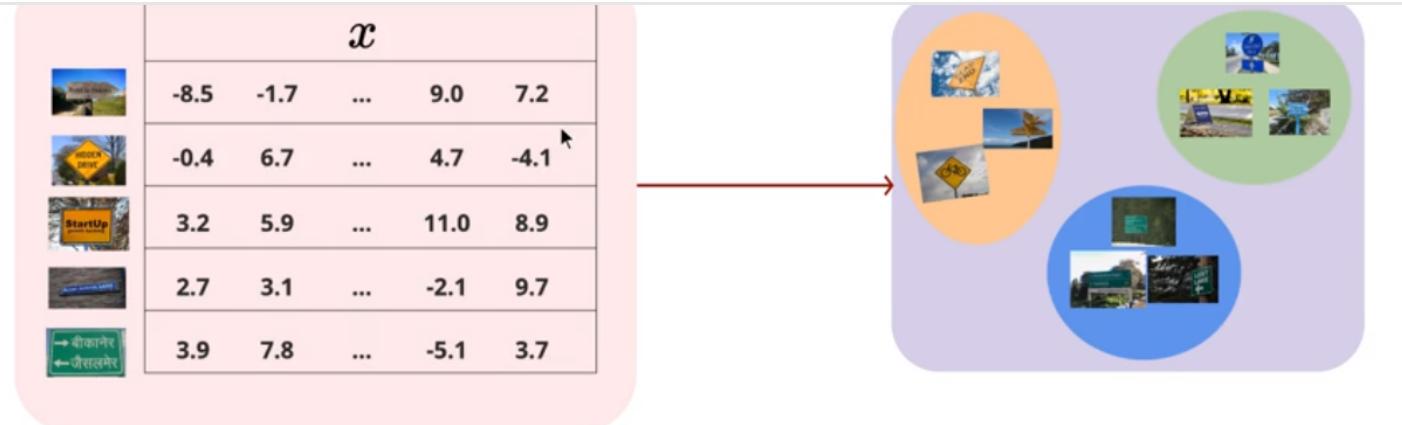
Another category of the task is Regression:

Supervised

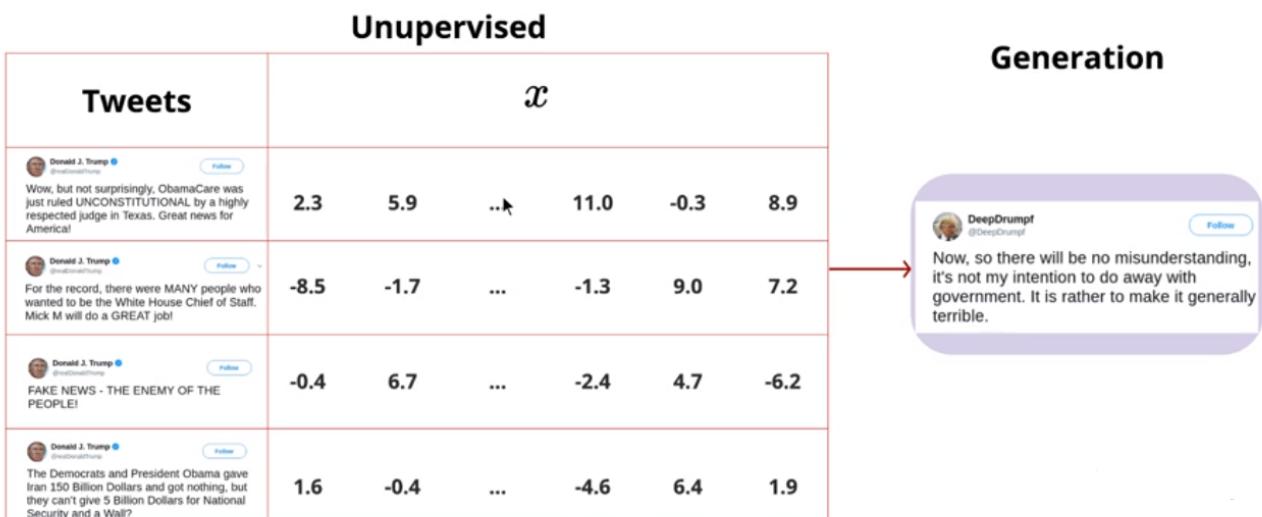
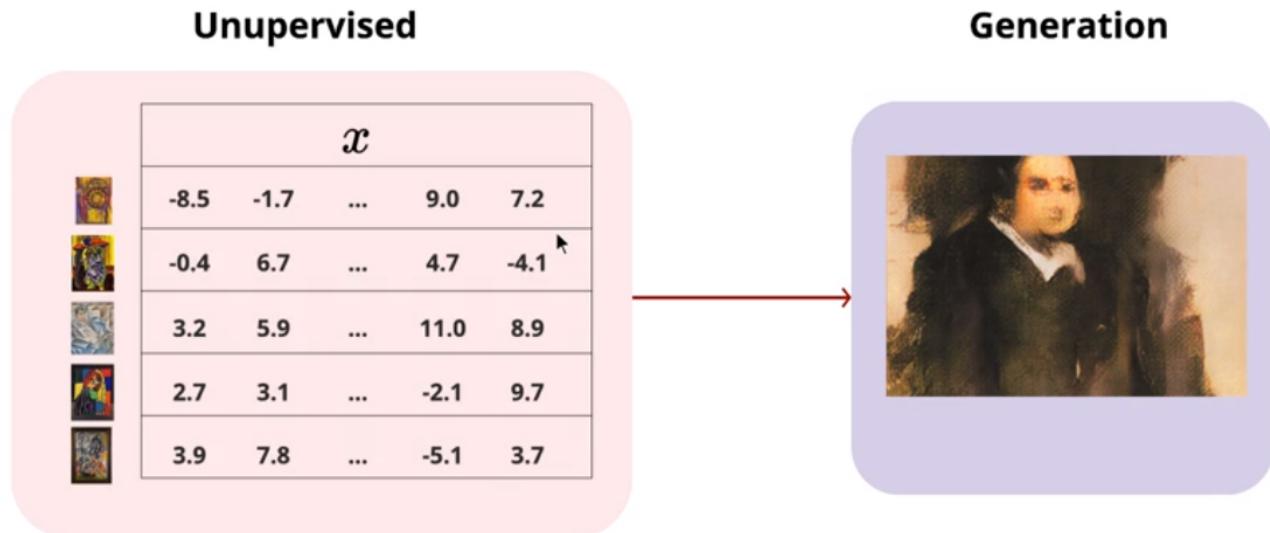
	\vec{x}					left_x	left_y	width	height
	-8.5	-1.7	...	9.0	7.2	2.3	1.2	9.2	10.1
	0.9	-2.1	...	-8.1	1.9	4.3	4.2	7.1	5.1
	2.9	-4.5	...	-3.7	8.9	2.3	7.2	6.9	7.3



Another category of tasks comes under Unsupervised Tasks and one particular task here is clustering:

[Open in app](#)

Another task is Generation:



Model:

So far we have discussed the Data and Task jar.

[Open in app](#) x  y

- bat
- car
- dog
- cat
- ship

 $[\ 2.1, 1.2, \dots, 5.6, 7.2 \]$ $[\ 0, 0, 1, 0, 0 \]$

Now we know that there is some true relationship that exists between the input and the output. The problem is that in most cases we don't know what this function is. What we typically do in machine learning is that we look at a lot of such data where we have x and y and in all of these cases we realize that there is some relation between x and y

 x  y

- bat
- car
- dog
- cat
- ship

[Open in app](#) x y

bat

car

dog

cat

ship

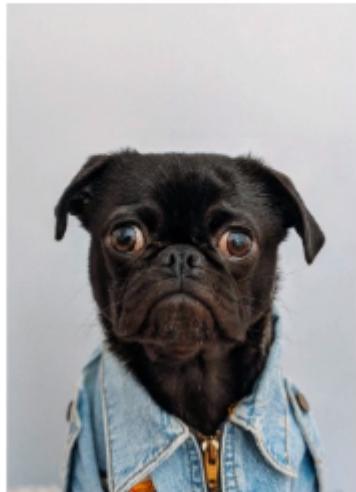
$$\begin{bmatrix} 2.1, 1.2, \dots, 5.6, 7.2 \\ 0.1, 3.1, \dots, 1.7, 3.4 \\ 0.5, 9.1, \dots, 5.1, 0.8 \\ 1.2, 4.1, \dots, 6.3, 7.4 \end{bmatrix}$$

$$\begin{bmatrix} 0, 0, 1, 0, 0 \\ 0, 1, 0, 0, 0 \\ 0, 0, 0, 0, 1 \\ 1, 0, 0, 0, 0 \end{bmatrix}$$

$$y = f(x) \text{ [true relation, unknown]}$$

Now what we do is, we say that we don't know what the True relation is(between the input and the output), we come up with some function which we believe best approximates the relation between x and y

$$\hat{y} = \hat{f}(x) \text{ [our approximation]}$$

[Open in app](#) x  y

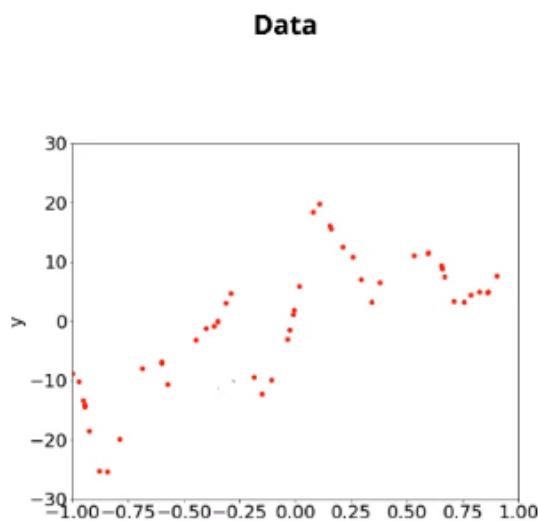
- bat
- car
- dog
- cat
- ship

$$\begin{bmatrix} 2.1, 1.2, \dots, 5.6, 7.2 \\ 0.1, 3.1, \dots, 1.7, 3.4 \\ 0.5, 9.1, \dots, 5.1, 0.8 \\ 1.2, 4.1, \dots, 6.3, 7.4 \\ 3.2, 2.1, \dots, 3.1, 0.9 \end{bmatrix} \quad \begin{bmatrix} 0, 0, 1, 0, 0 \\ 0, 1, 0, 0, 0 \\ 0, 0, 0, 0, 1 \\ 1, 0, 0, 0, 0 \\ 0, 0, 1, 0, 0 \end{bmatrix}$$

Let's understand this in much more detail.

We take one-dimensional data and plot it out

$$\begin{array}{c} x \\ \hline 0.5 \\ 0.2 \\ 0.6 \\ \dots \\ 0.3 \end{array} \quad \begin{array}{c} y \\ \hline 14.8 \\ 13.3 \\ 11.6 \\ \dots \\ 6.16 \end{array}$$

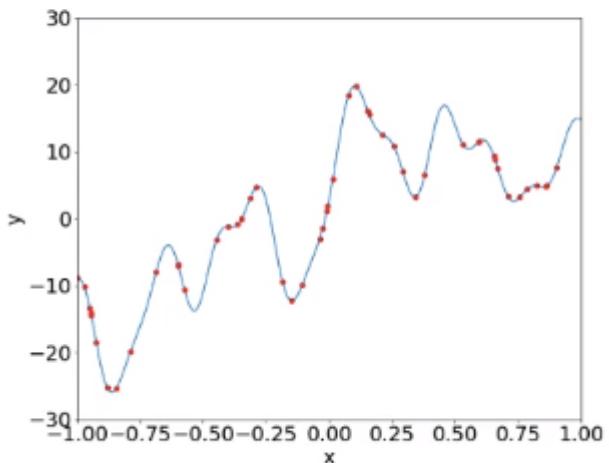



[Open in app](#)

True relation between x and y is:

x	y
0.5	14.8
0.2	13.3
0.6	11.6
...	...
0.3	6.16

Data is drawn from the following function

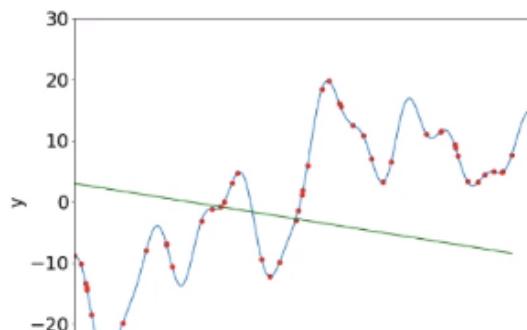


But we do not know the true function and will only have the data and using the data we need to come up with a function. So, we start with a very simple function say a linear function.

$$\hat{y} = mx + c$$

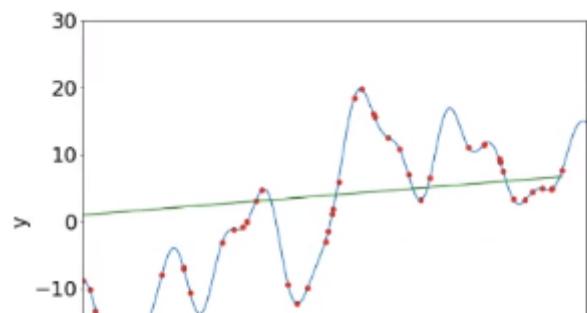
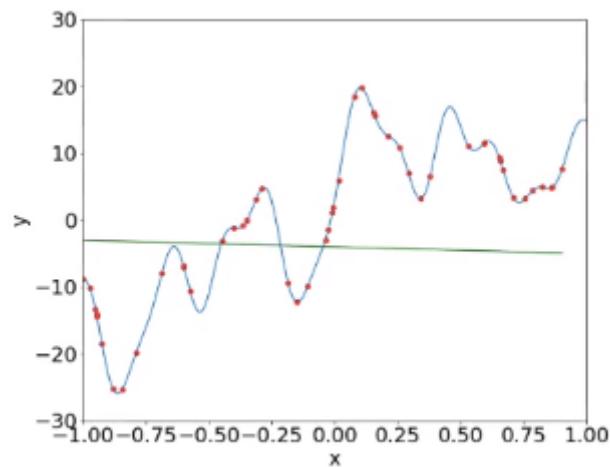
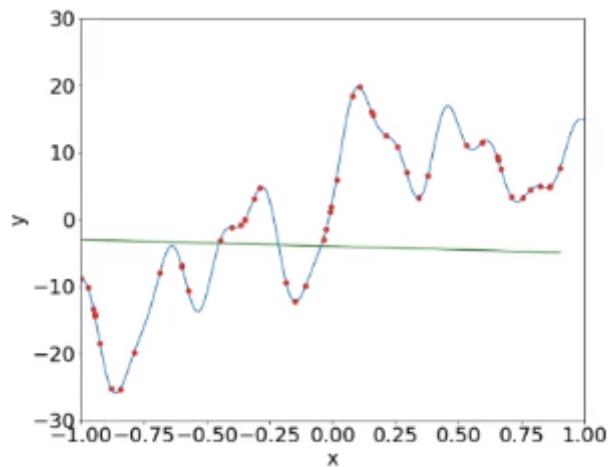
x	y
0.5	14.8
0.2	13.3
0.6	11.6
...	...
0.3	6.16

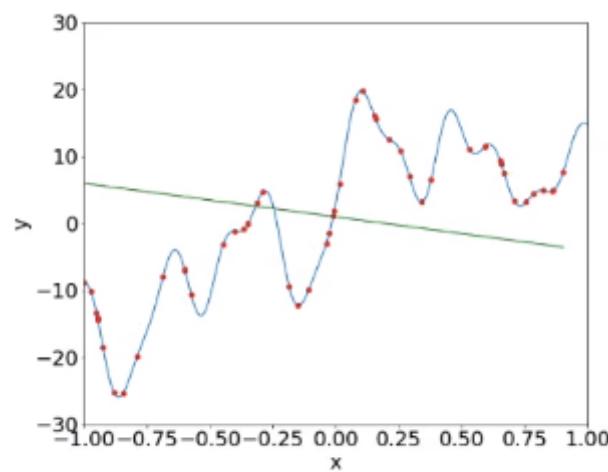
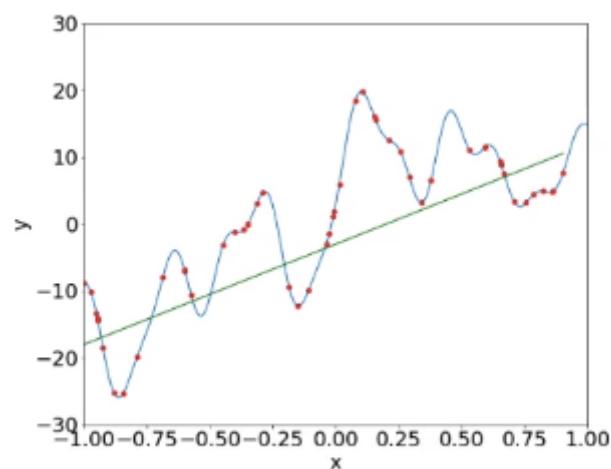
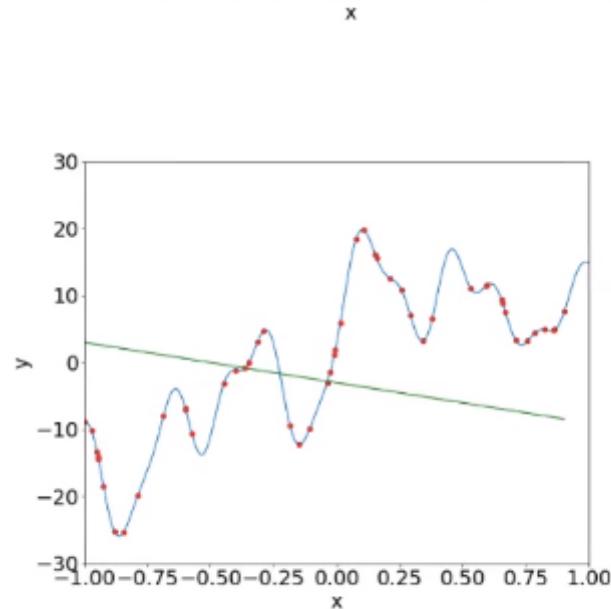
Data is drawn from the following function



[Open in app](#)

The parameters m and c are learned using all the data that we have. We can learn these two parameters even if we have just 2 data points but the problem here is that no matter how we adjust these parameters m and c , we can not come up with a line that passes through all of these points.

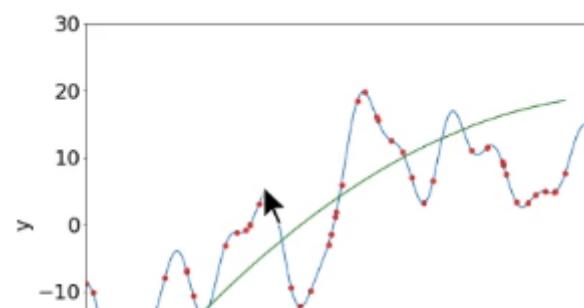
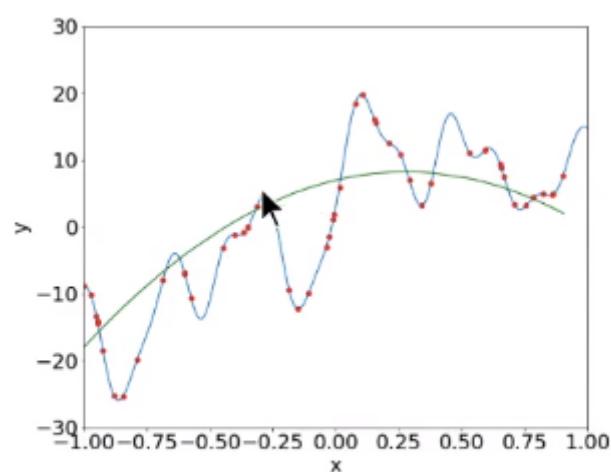
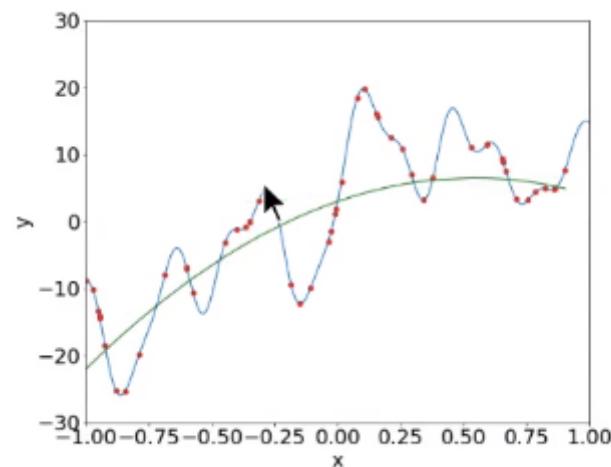


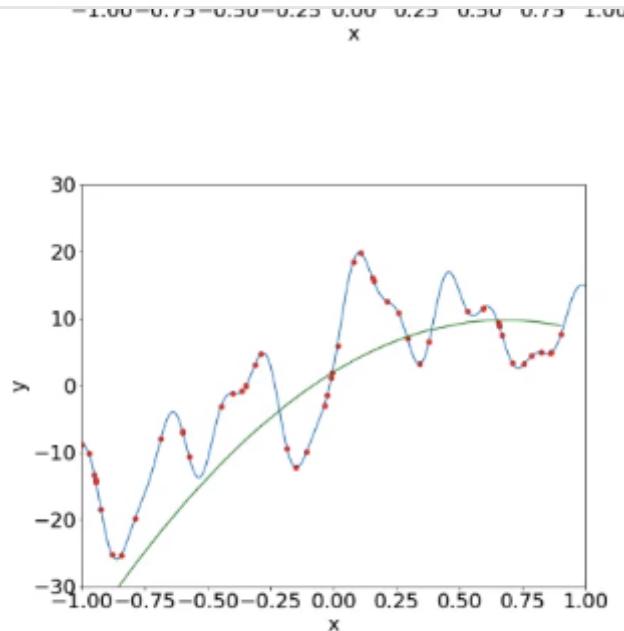
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data.

$$\hat{y} = ax^2 + bx + c$$



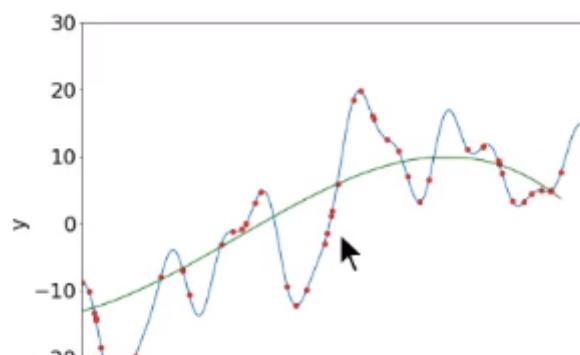
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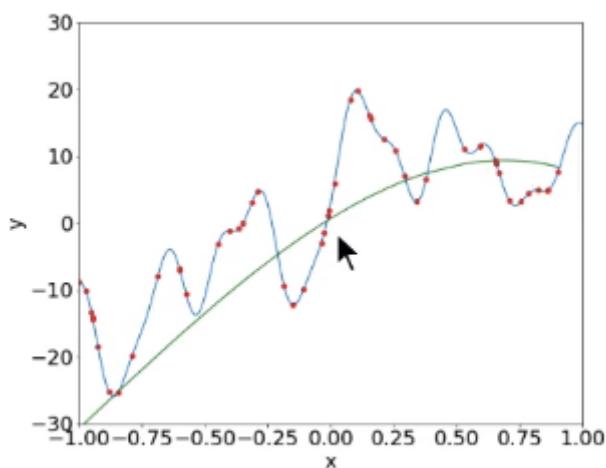
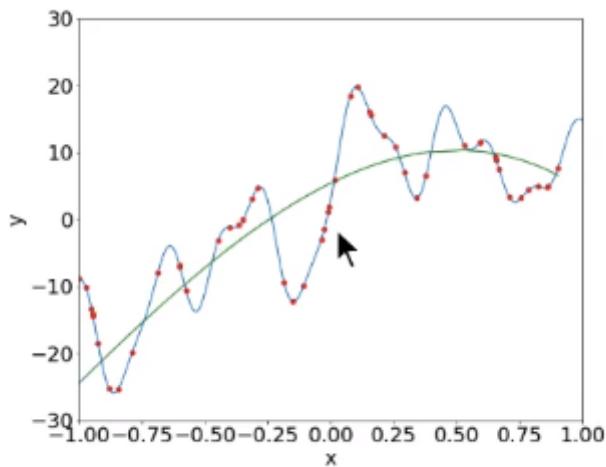
Here also we see that no matter what different values of a, b and c we try, we are not able to get a situation where for any given x here the output of the function(green curve) is the same as the red point(corresponding to the same x). So, this function is also not complex enough to capture the relationship between x and y.

The machine is trying to find the values of the parameters very efficiently in such a way that the value of error is minimum that means we should be as close to the predictions as possible.

So, we try again with degree 3 polynomial.

$$\hat{y} = ax^3 + bx^2 + cx + d$$



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And once again the same story repeats, we try to adjust the values of a, b, c and d such that the green curve is as close to the red dots as possible.

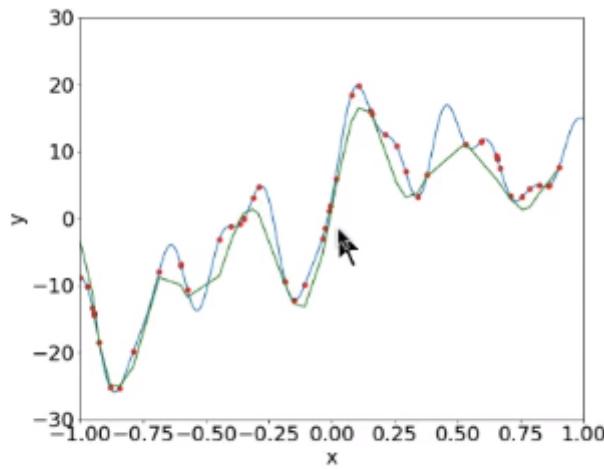
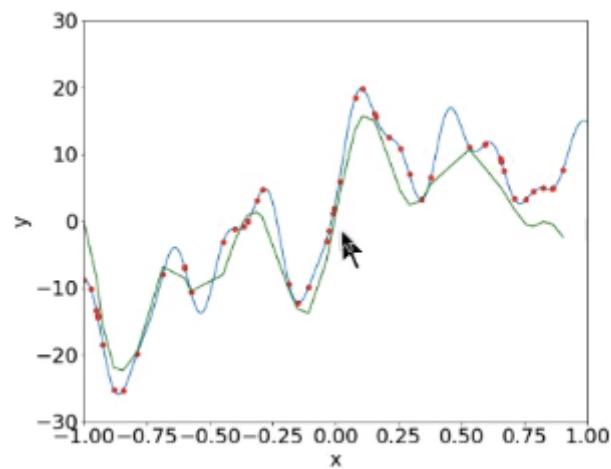
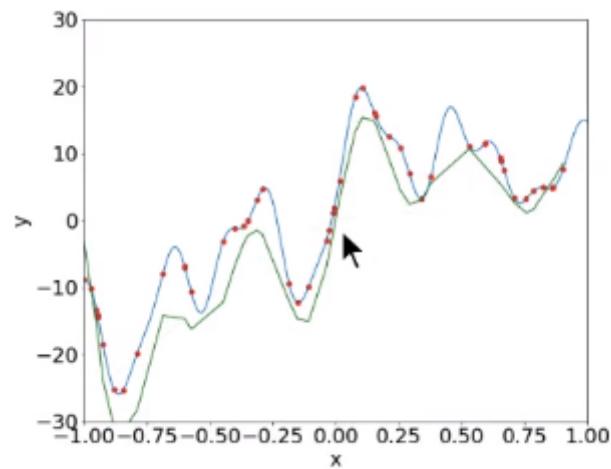
And we keep trying this with higher degree polynomials until we reach to degree 25 polynomial which is coming very close not exactly overlapping with the red points but still very close and captures the relationship between x and y.

$$\hat{y} = ax^4 + bx^3 + cx + d$$

⋮

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y — w w w w w w w w



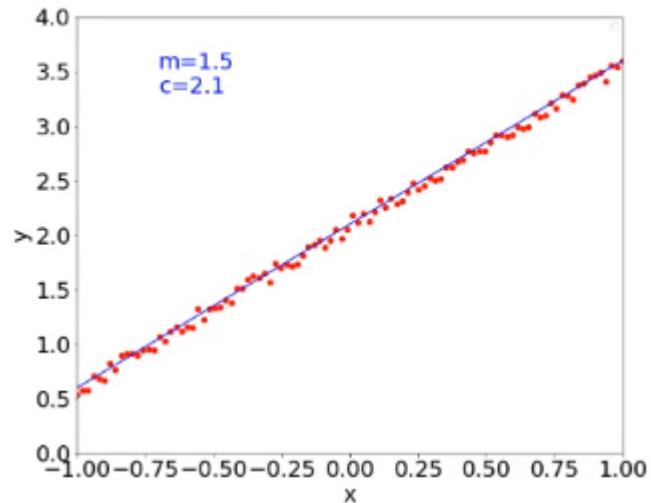
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And in most of the real-world problems, data would be a high dimensional meaning we could not just plot this out and visualize which function would be the best fit for this data set.

One question that arises now is that why not try a very complex model from the very beginning?

The reason for this is that suppose the true relation between x and y is very close to a line.

x	y
0.1	2.6
0.2	2.4
0.4	3.1
....
0.8	4.1

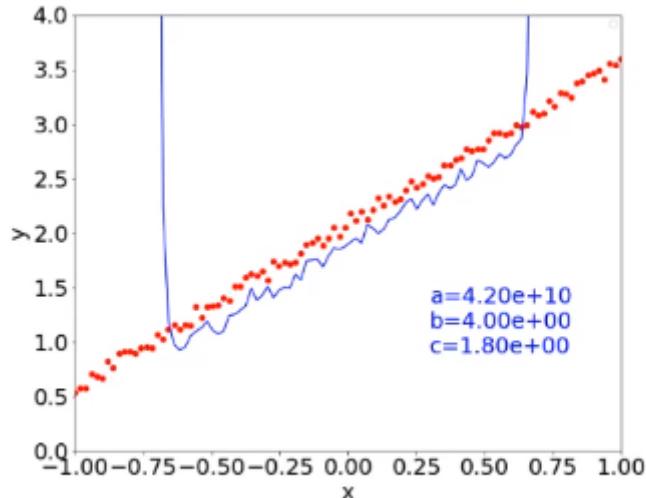


$$y = mx + c \text{ [true function, simple]}$$

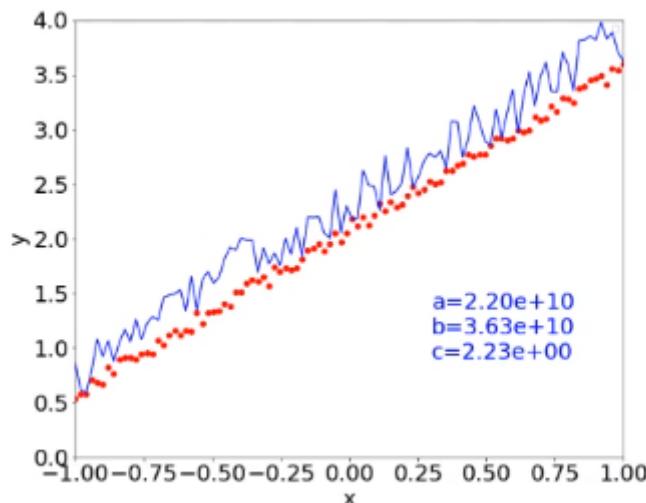
And what if we try it to approximate using a very complex function which is say a 100-degree polynomial

$$\hat{y} = ax^{100} + bx^{99} + \dots + mx + c$$

[our approximation, very complex]

[Open in app](#)

In this case, we could say that the machine should be able to find all the parameters such that all the parameters except m and c are zero, that means we could still start with a very complex function and the machine could learn to ignore it and come up with a very simple function. But if we try this, then we would get stuck at a point where it would be very difficult for the machine to learn all these 98 parameters to be 0. Although it seems easy for a human being, the machine has to try out all these values and out of these infinite values, it has to find out this exact peculiar case where all the parameters are 0 except m and c . So, in practice, it would be very difficult for the machine to do that.



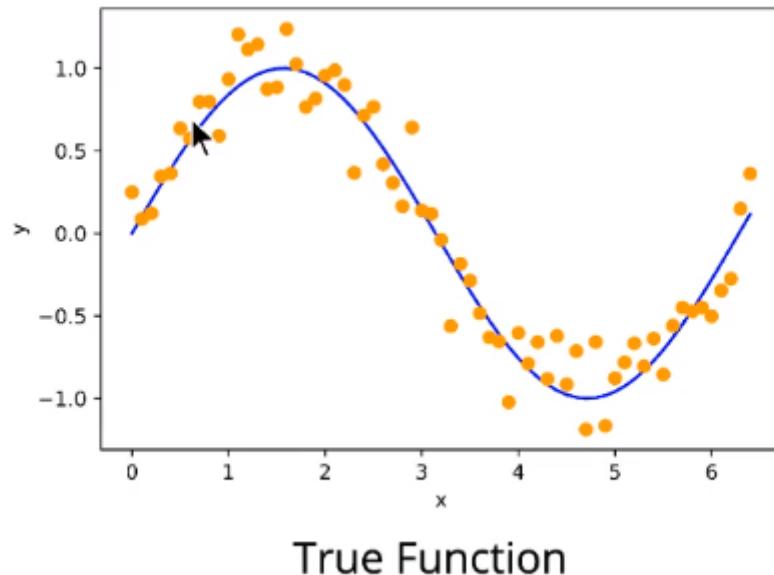
Loss Function:

How do we know which model is better?

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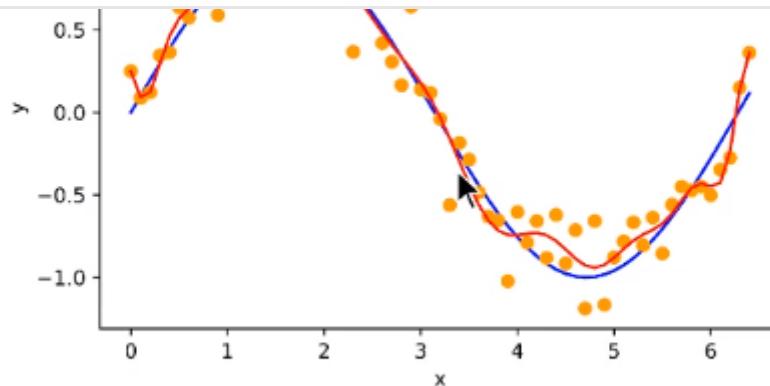
	x	y
1	0.00	0.24
2	0.10	0.08
3	0.20	0.12
....
n	6.40	0.36

And the following is the **true relation** between x and y which is something very close to the sine function along with some noise.



Someone approximates this function as

$$\hat{f}_1(x) = 1.79x^{25} - 4.54x^{24} + \dots - 1.48x + 2.48$$

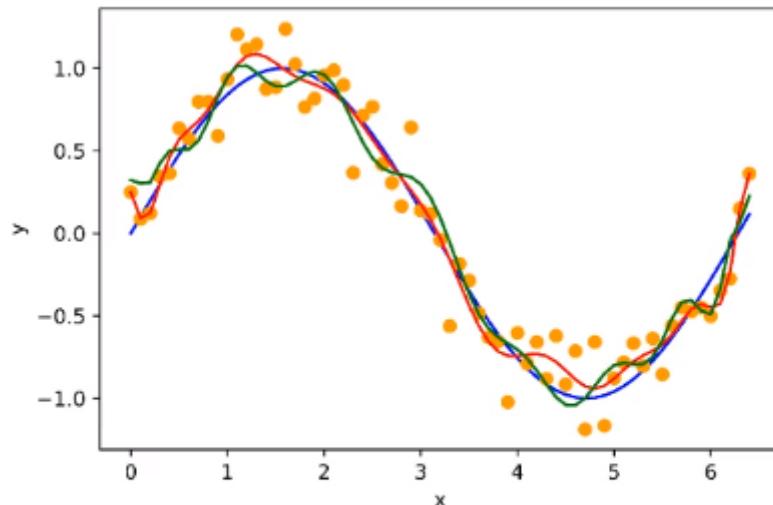
[Open in app](#)

$$\hat{f}_1(x)$$

Red curve

Now another person has come up with let's say the below function:

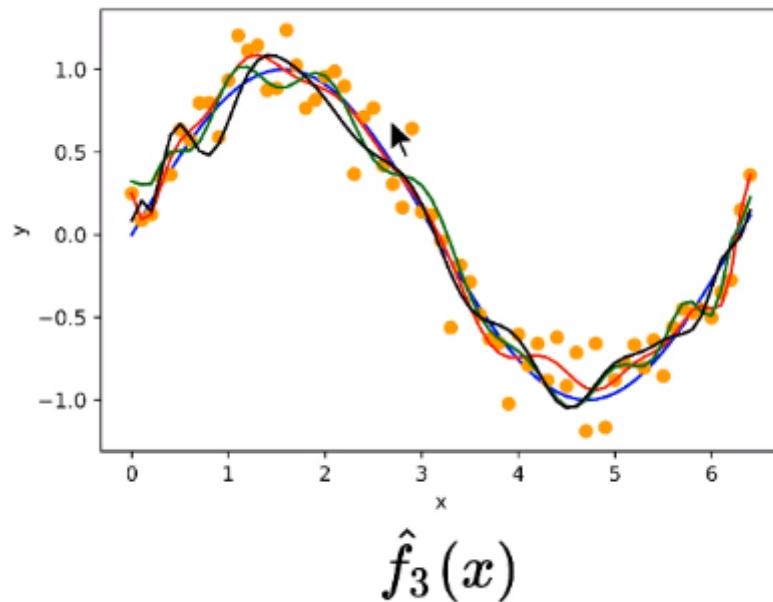
$$\hat{f}_2(x) = 2.27x^{25} + 9.89x^{24} + \dots + 2.79x + 3.22$$



$$\hat{f}_2(x)$$

Green curve

Now the third person came up with the following function:

[Open in app](#)

Black Curve

All these 3 functions seem to be very close to the sine function. Now the question is which of these functions is better?

If we try to visually inspect, it's not very clear as all the curves are very close to each other and to the true curve. So, instead of looking at the curves, we could look at some numbers and decide which function is better.

	x	y	$\hat{f}_1(x)$	$\hat{f}_2(x)$	$\hat{f}_3(x)$
1	0.00	0.24	0.25	0.32	0.08
2	0.10	0.08	0.09	0.30	0.20
3	0.20	0.12	0.11	0.31	0.14
....
n	6.40	0.36	0.36	0.22	0.15

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+ve value of error does not cancel out with the -ve value of error and there is also a calculus-based reason for this) of the difference between the true output and the predicted values for all the data points.

$$\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}_1(x_i))^2$$

$$\mathcal{L}_2 = \sum_{i=1}^n (y_i - \hat{f}_2(x_i))^2$$

$$\begin{aligned}\mathcal{L}_1 &= \sum_{i=1}^n (y_i - \hat{f}_1(x_i))^2 \\ &= (0.24 - 0.25)^2 + (0.08 - 0.09)^2 + (0.12 - 0.11)^2 + \\ &\quad \dots + (0.36 - 0.36)^2 \\ &= 1.38\end{aligned}$$

In a similar way, we could compute this error value for all the three functions that we approximated.

$$\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}_1(x_i))^2 = 1.38$$

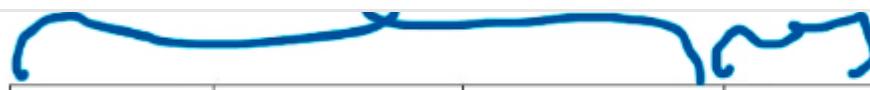
$$\mathcal{L}_2 = \sum_{i=1}^n (y_i - \hat{f}_2(x_i))^2 = 2.02$$

$$\mathcal{L}_3 = \sum_{i=1}^n (y_i - \hat{f}_3(x_i))^2 = 2.34$$

And now based on this error value we could say that the first approximation was better than the other two. So, a loss function helps us decide how good or bad our model is or how good or bad our parameters are. And it also helps to decide the better model among a given set of models.

Learning Algorithm:

We have been provided with the Data and the task as well:

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Budget in (100crs)	Box Office Collection in (100 crs)	Action Scene in times (100 mins)	IMDB Rating
0.55	0.66	0.22	4.8
0.68	0.91	0.77	7.2
0.66	0.88	0.67	6.7
:	:	:	:
0.72	0.94	0.97	8.1
0.58	0.74	0.35	5.3

We have also proposed a model as the following

$$\hat{f}(x) = ax_1^2 + bx_2^3 + cx_3^2$$

Let's say somehow we also got the parameters of this model as:

$$\hat{f}(x) = 3.5x_1^2 + 2.5x_2^3 + 1.2x_3^2$$

Then we can check the error value of this model as using the below:

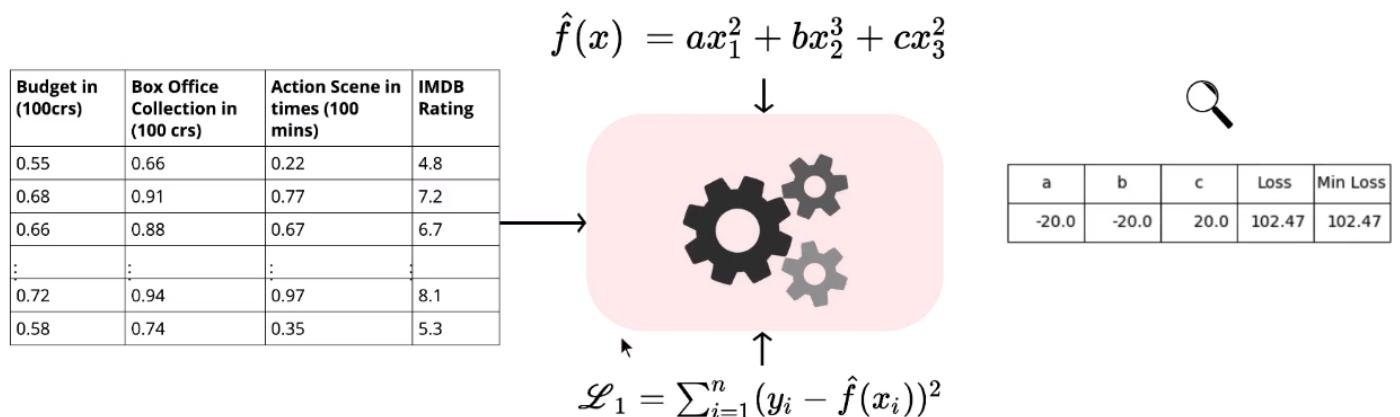
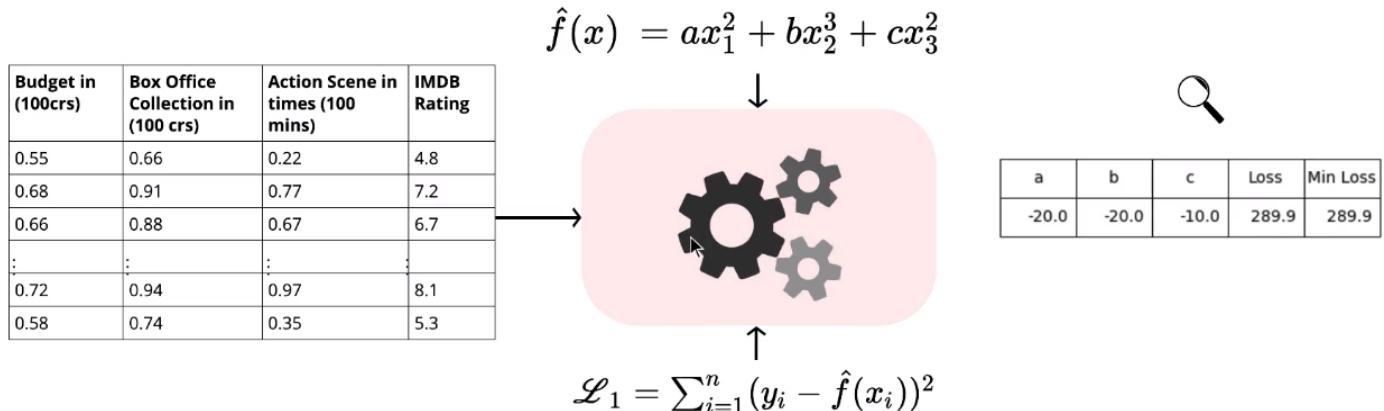
$$\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}(x_i))^2$$

Till now we have the Data, Task, Model, and Loss function. We don't have a way to learn the parameters of the model.

Learning Algorithm helps us to learn the parameter of the model.

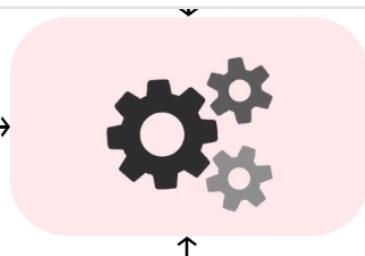
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We could then fix the value of the **a** and **b** both to -20 and then search across **c**(try out different value from -20 to 20) and plug these values into the Loss function(plug into model equation, then compute the predicted output and from there we compute the loss) and see what value of **c** gives the best result. And then we repeat the process and do the same thing and find the value of **b** for which the loss is minimum. In other words, in this entire space of -20 to 20, for all values of **a**, **b** and **c**, we compute the loss value by plugging in these values of **a**, **b** and **c** in the model/function and using in the Loss function equation. We also keep track of the minimum loss.




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Budget in (100crs)	Collection in (100 crs)	times (100 mins)	Rating
0.55	0.66	0.22	4.8
0.68	0.91	0.77	7.2
0.66	0.88	0.67	6.7
:	:	:	:
0.72	0.94	0.97	8.1
0.58	0.74	0.35	5.3



a	b	c	Loss	Min Loss
-20.0	0.0	-20.0	200.98	63.79

$$\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}(x_i))^2$$

Budget in (100crs)	Box Office Collection in (100 crs)	Action Scene in times (100 mins)	IMDB Rating
0.55	0.66	0.22	4.8
0.68	0.91	0.77	7.2
0.66	0.88	0.67	6.7
:	:	:	:
0.72	0.94	0.97	8.1
0.58	0.74	0.35	5.3

$$\hat{f}(x) = ax_1^2 + bx_2^3 + cx_3^2$$



a	b	c	Loss	Min Loss
-20.0	10.0	-10.0	82.12	40.96

$$\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}(x_i))^2$$

Budget in (100crs)	Box Office Collection in (100 crs)	Action Scene in times (100 mins)	IMDB Rating
0.55	0.66	0.22	4.8
0.68	0.91	0.77	7.2
0.66	0.88	0.67	6.7
:	:	:	:
0.72	0.94	0.97	8.1
0.58	0.74	0.35	5.3

$$\hat{f}(x) = ax_1^2 + bx_2^3 + cx_3^2$$



a	b	c	Loss	Min Loss
20.0	20.0	-10.0	3.74	3.74

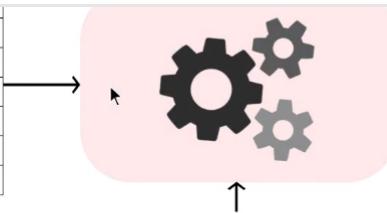
$$\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}(x_i))^2$$

At the end of this search process, we will get some value of a, b and c for which the loss is minimized. And we will just output those values. And that would be the parameter configuration for which the loss is minimized.

So, this is a very brute force approach. In practice, this brute force approach would not be feasible because we would not only have just 3 parameters, we would have thousands of values. So, what we need is an efficient way of computing these parameters.


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0.55	0.66	0.22	4.8
0.68	0.91	0.77	7.2
0.66	0.88	0.67	6.7
:	:	:	:
0.72	0.94	0.97	8.1
0.58	0.74	0.35	5.3



a	b	c	Loss	Min Loss
20.0	20.0	-10.0	3.74	3.74

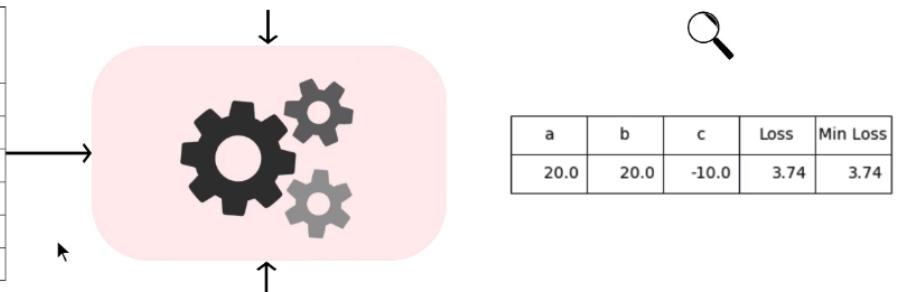
- ✖ In practice, brute force search is infeasible

Find a, b, c such that
 $\mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}(x_i))^2$
is minimized

So, now this is converted to an optimization problem. **We need to find values of a, b and c for which the Loss value is minimized.** So, we have a function(Loss function) which depends on the values of a, b and c and we want to find the values of a, b, and c such that the value of that function is minimized.

Budget (100crore)	Box Office Collection(100 crore)	Action Scene times (100 mins)	IMDB Rating
0.55	0.66	0.22	4.8
0.68	0.91	0.77	7.2
0.66	0.88	0.67	6.7
:	:	:	:
0.72	0.94	0.97	8.1
0.58	0.74	0.35	5.3

$$\hat{f}(x) = ax_1^2 + bx_2^3 + cx_3^2$$



a	b	c	Loss	Min Loss
20.0	20.0	-10.0	3.74	3.74

- ✓ Many optimization solvers are available

$$\min_{a,b,c} \mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}(x_i))^2$$

And the way we go about computing the parameters which give the minimum value of the Loss function lies in the Calculus where we take the partial derivative of the function with respect to the parameter(s) and equate this to 0 to get the value of the parameter(s) for which the function's value would be minimum.

Evaluation:

How do we evaluate our model?

Let's say we are building an image classifier. We pass the data through the model, predict the output and we also know the true values/labels

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	[2.1, 1.2, ..., 5.6, 7.8]	1	1	
	[3.5, 6.6, ..., 2.5, 6.3]	2	3	
	[6.3, 2.6, ..., 4.5, 3.8]	3	1	
	[2.8, 3.6, ..., 7.5, 2.1]	4	4	
	[2.2, 1.7, ..., 2.5, 1.8]	5	5	
	[6.3, 2.6, ..., 4.5, 3.8]	3	2	
	[1.9, 3.3, ..., 4.2, 1.1]	5	5	

Class Labels	
Lion	1
Tiger	2
Cat	3
Giraffe	4
Dog	5

And we can just compute the accuracy of the model. The way we do this is that for each instance we compare the output predicted by the model with the true output. So, in the above image, out of the total 7 cases provided, the model predicted the correct output in 4 cases. And the accuracy, in this case, would be:

$$\text{Accuracy} = \frac{\text{Number of correct predictions}}{\text{Total number of predictions}}$$

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So, this is one way of evaluating the models. In many practical situations, we might look at the top three outputs given by the model and we are okay as long as one of those three matches the true output. And this is termed as Top-3 accuracy or in general Top-k accuracy if we are looking at the top k outputs.

Top - 3

	True Labels	Predicted Labels	
	[2.1, 1.2, ..., 5.6, 7.8]	1	[1, 2, 3]
	[3.5, 6.6, ..., 2.5, 6.3]	2	[1, 2, 3]
	[6.3, 2.6, ..., 4.5, 3.8]	3	[1, 2, 3]
	[2.8, 3.6, ..., 7.5, 2.1]	4	[4, 5, 3]
	[2.2, 1.7, ..., 2.5, 1.8]	5	[5, 2, 1]
	[6.3, 2.6, ..., 4.5, 3.8]	3	[2, 1, 4]
	[1.9, 3.3, ..., 4.2, 1.1]	5	[5, 4, 1]

$$\text{Accuracy} = \frac{\text{Number of correct predictions in top-3}}{\text{Total number of predictions}}$$

$$= \frac{6}{7} = 0.86 \quad \blacktriangleright$$

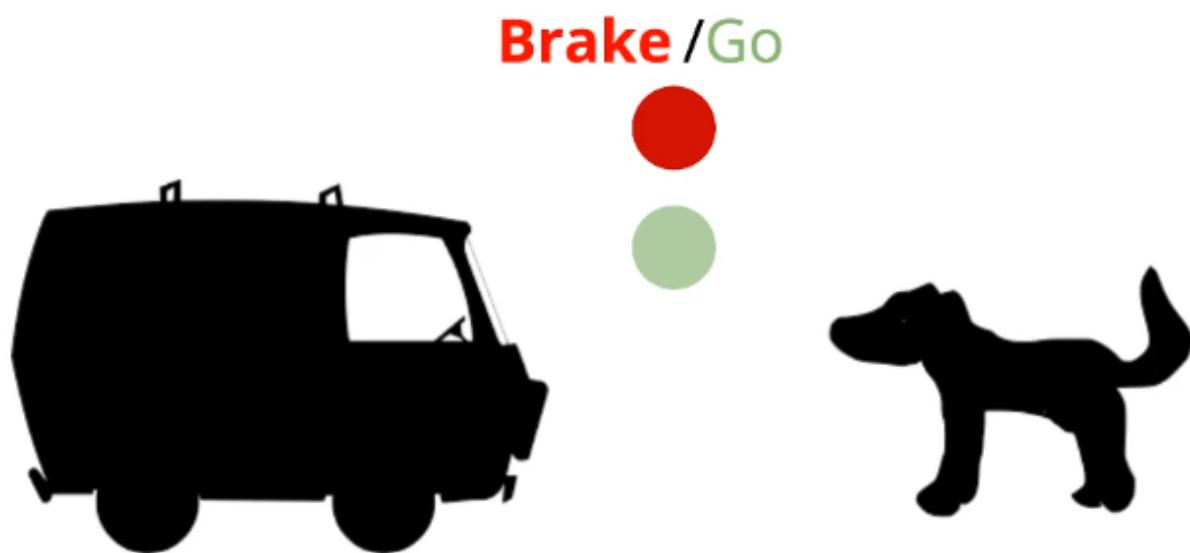
Now the question arises is that, how this is different from the Loss Function?

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if we are told that the Square Error loss is 0.4, it's hard for us to judge how good or bad our model is.

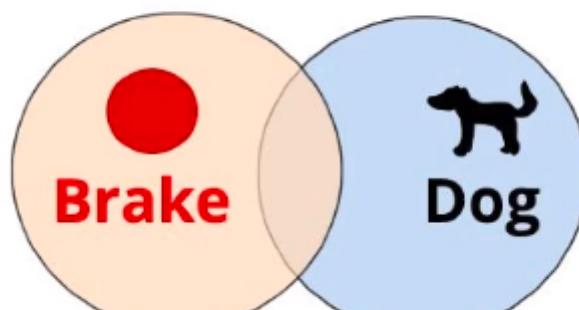
And here is also some practical intuition why we should have a different measure for Loss function and different measures for evaluating the model:

So, think of this practical application where we building an autonomous driving car and one module would be to deciding whether to apply the brake or not depending on if there is an obstacle(like a dog) or not.



So, the model's job is to apply break whenever there is an obstacle and if there is no dog(let's say the dog is the only obstacle on the road), then the car should just keep going. The standard evaluation metric for this case is something known as precision and recall and we calculate/understand it using the Venn diagram.

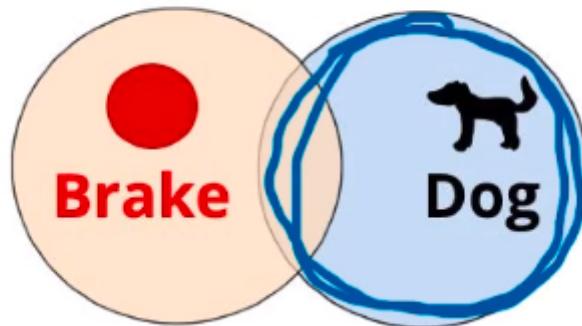
Evaluation



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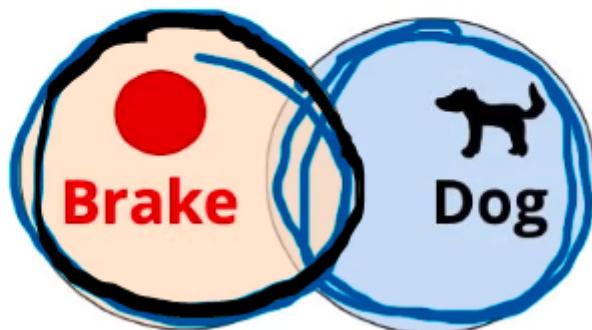
In the below image, the highlighted (circled) portion indicates all the cases when there was an obstacle on the road.

Evaluation



And the highlighted portion(in black) in the below image represents all the cases when the model decided to apply the brake.

Evaluation



In a perfect world, we would like the two circles to be perfectly overlapping meaning every time there was a dog we applied the brake, and whenever we applied the brake there was some obstacle. We never applied the brake when there was no obstacle or dog.

Brake circle represents the total number of times we applied the brake and the intersection region represents the number of times when we correctly applied the

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And recall in this case would be the total number of times there was a dog and we applied the brake(intersection part) divided by the total number of times the dog was there. So, precision is very intuitive, that the number of times you took the correct action out of the total number of times you took an action, of all the times you took an action how many times were you correct.

And recall is of how many times you were supposed to take any action, how many times did you actually take an action.

So, this Precision and recall we could call as Evaluation metric.

But if we were to train this model, we could use a Loss function which tries to maximize the distance between the car and the obstacle(we don't want to apply the brake very close to the dog, there might be a possibility of hurting the dog or some unknown event there). So, that's how we would like to train our model to not just learn when to apply the brake but to also maximize the distance between the car and obstacle.

Loss function

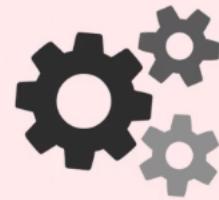


So, as is clear from this example the Loss function and Evaluation metrics are very different.

All the work till now be it Data, Task definition, training the model so that Loss is minimized was on the training data. Once the model is trained on the training data, it needs to perform well on the test set as well. **So, the evaluation is never on the training data, it's always on the test data.**


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	$2.1, 1.2, \dots, 5.6, 7.8$	1
	$3.5, 6.6, \dots, 2.5, 6.3$	2
	$6.3, 2.6, \dots, 4.5, 3.8$	3
	$2.8, 3.6, \dots, 7.5, 2.1$	4
	$2.2, 1.7, \dots, 2.5, 1.8$	2



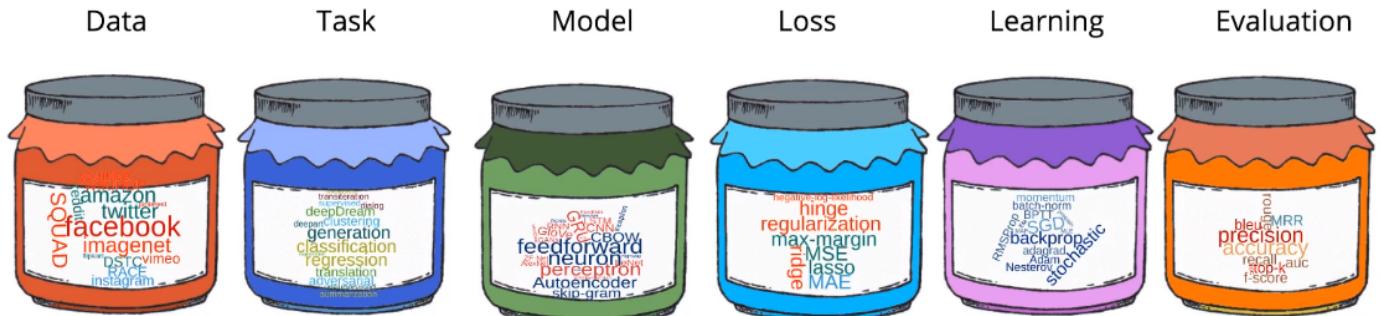
$$\min_{a,b,c} \mathcal{L}_1 = \sum_{i=1}^n (y_i - \hat{f}_1(x_i))^2$$

Test Data

	x	y
	$[6.3, 2.6, \dots, 4.5, 3.8]$	1
	$[2.8, 3.6, \dots, 7.5, 2.1]$	3
	$[2.2, 1.7, \dots, 2.5, 1.8]$	4

$$\text{Accuracy} = \frac{\text{Number of correct predictions}}{\text{Total number of predictions}}$$

So, with this, we complete the jars of Machine Learning.



This article covers the content covered in the Expert Systems — 6 Jars module of the [Deep Learning course](#) and all the images are taken from the same module.

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